Using Low-Level Aerial Photography to Measure Structural Features

Alberta Foothills Disturbance Ecology Methodology Series
Report No. 2

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Foothills Model Forest
October 2005

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LANDSCAPE-ECOSYSTEM SERVICES

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MODEL FOREST
research growing into practice.

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Foothills Model Forest is one of eleven Model Forests that make up the Canadian Model Forest Network. As such, Foothills Model Forest is a non-profit organization representing a wide array of industrial, academic, government and non-government partners, and is located in Hinton, Alberta. The three principal partners representing the agencies with vested management authority for the lands that comprise the Foothills Model Forest, include Hinton Wood Products, A Division of West Fraser Mills Ltd., Alberta Sustainable Resource Development and Jasper National Park. These lands encompass a combined area of more than 2.75 million hectares under active resource management.

The Canadian Forest Service of Natural Resources Canada is also a principal partner in each of the eleven Model Forest organizations and provides the primary funding and administrative support to Canada's Model Forest Program.

The Foothills Model Forest mission: We are a unique partnership dedicated to providing practical solutions for stewardship and sustainability on Alberta forestlands. What we learn will be:

- reflected in on-the-ground practice throughout Alberta and elsewhere in Canada, where applicable
- incorporated in forest and environmental policy and changes;
- widely disseminated to and understood by a broad spectrum of society.

This will be the result of a solid, credible, recognized program of science, technology, demonstration and outreach.

ACKNOWLEDGEMENTS

This research was possible only through the hard work and dedication of many individuals. First and foremost, Hinton Wood Products, A Division of West Fraser Mills Ltd., Jasper National Park, the Canadian Forest Service, Alberta Newsprint Company, and Alberta Sustainable Resource Development generously supported the natural disturbance research presented in this report.

The Foothills Model Forest (FtMF) Natural Disturbance Program was the vision of two individuals; Hugh Lougheed from Weldwood of Canada Ltd., and Dan Farr, then with the Foothills Model Forest. Since then, the unflagging support of the FtMF Natural Disturbance activity team is reflected in the thoroughness of the research, and quality of the data. We would like to thank Dan, Hugh, Gord Stenhouse (then with Weldwood), George Mercer, Al Westhaver and Dave Smith from Jasper National Park, Don Harrison, Herman Stegehuis, and Bob Anderson from Alberta Sustainable Resource Development, Greg Branton from Alberta Newsprint Company, and Rick Blackwood, Mark Storie and Don Podlubny from the Foothills Model Forest for their perpetual faith and support. Also, many thanks to the FMF Board of Directors, and in particular Bob Udell, for their unrelenting belief in the Natural Disturbance Program.

The FtMF Natural Disturbance Program was fortunate to receive funding for this project from the Chisholm-Dogrib Fire Research Project. Thank you to Kim MacLean and Scott Wilson for completing the field work portion of this project and Derrick Lalonde of Timberline Forest Inventory Consultants for completing the photo interpretation. This was a co-operative project with the Foothills Model Forest Fish and Watershed Research Program.

EXECUTIVE SUMMARY

This is the second report in the FtMF Natural Disturbance Program methodology series. In this report we describe and critique how we collected data for the Managing Natural Disturbance In Riparian Areas project. We detail how we collected data in both the field and on aerial photos to document stand dynamics following fires. The methods we used were necessarily new and experimental (as we are not familiar with other similar research projects). We found that aerial photos taken at the scale of approximately 1:1800 do not provide adequate resolution to identify structural features to our desired level of precision. Hopefully the information gained and lessons we learned through this project will help guide other researchers who are undertaking similar projects.

INTRODUCTION AND REPORT OVERVIEW

This report is divided into several related parts:

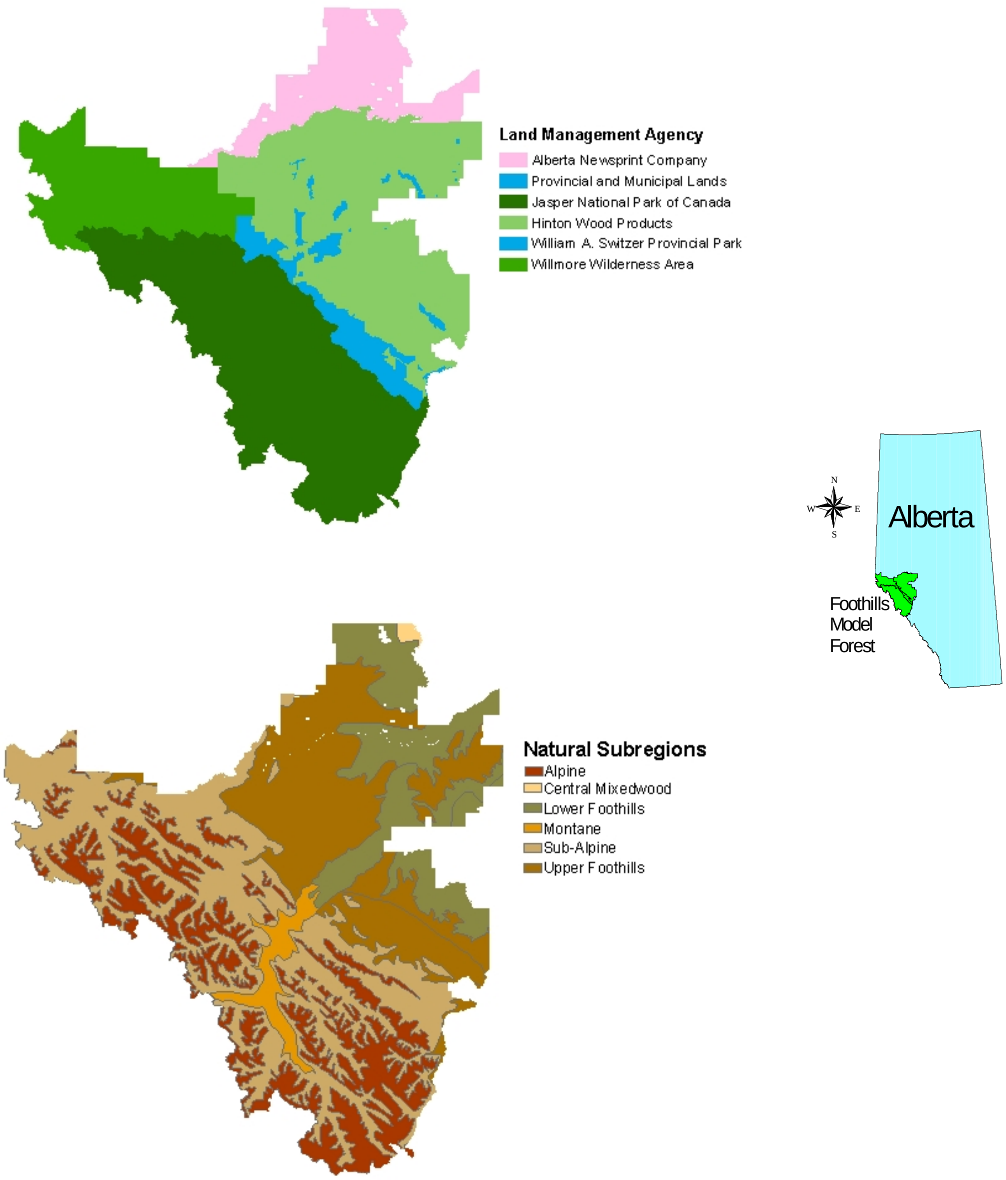
Part 1 is a general overview of the FtMF Natural Disturbance Program, and is common to all reports in the research and methodology series.

Part 2 details and critiques the methods we used during this project and gives results.

Appendix 1 contains the aerial photos used in this project.

Part 1: THE FtMF NATURAL DISTURBANCE PROGRAM

In 1995, the Foothills Model Forest (FtMF) in Hinton, Alberta initiated a research program to describe natural and cultural disturbance patterns across over 2.5 million hectares of foothills and mountain landscapes (Figures 1 and 2). The main purpose of the research was to provide to Model Forest partners and co-operators with a complete picture of how natural and cultural disturbances have historically shaped these landscapes. Ultimately, each partner intends to use this information to help guide policy and management towards developing more ecologically sustainable land management practices.



Figures 1 and 2. Foothills Model Forest administrative areas and ecological zones.

The Foothills Model Forest Natural Disturbance Program is a co-operative venture, led by a team of representatives from the Foothills Model Forest, Hinton Wood Products, A Division of West Fraser Mills Ltd., Alberta Sustainable Resource Development Public Lands and Forests (SRD), Jasper National Park (JNP), and Alberta Newsprint Company (ANC). The comprehensive research program is partitioned into over 40 inter-related projects, each of which address a single disturbance question at a single scale. All projects are linked through a long-term research plan (Andison 1999a), which includes details of the purpose and methods for each project, and how they link together to form a complete picture of natural disturbance patterns. It also defines ground-rules for conducting the research to maintain focus, assess progress, respond to new information, and effect the timely completion of the work. These ground-rules are as follows:

1) The main assumption driving this research program is: In the absence of information on alternatives, using natural disturbance patterns to guide management is one of the best possible means of achieving ecological sustainability. Therefore, the main research focus is on patterns, and the disturbance processes responsible for those patterns. This is not to say that the ecological responses to those patterns are not important, but they are secondary issues/questions for which more basic knowledge is required (which we do not yet possess).

2) Since both natural and cultural disturbance affect pattern, the program implicitly considers all types of disturbances. The danger of the deliberate isolation and study of different types of disturbance agents is the assumption of pre-conceived, and possibly incorrect, relationships between pattern and process.

3) The research is driven by operational needs, and the results are designed to be readily interpreted. This means that the research must consider translations of results to management practices. This can be accomplished in two ways. First, direct linkages have been sought to biodiversity monitoring programs through the description of pattern(s). Although the output of this research is non-species specific, it is highly quantitative, and thus ideally suited to this task. The second means of developing operational translations is through experimentation. This allows for the evaluation of operational changes in terms of a) the success of creating the desired pattern(s), b) the biological responses of species and processes not part of the original research, c) practicality, and d) socio-economic impacts.

4.) Finally, internalizing the research is to be avoided. High-quality research must be conducted by professionals, openly peer-reviewed, presented at public meetings, conferences and tours, and published in pamphlets, internal reports, news updates, posters, and refereed journals. A communications plan has been developed for the natural disturbance program to address these issues to guide the distribution of the research.

SOME DEFINITIONS

The term "landscape" has many meanings at many different scales. Throughout the program and this document, a "landscape" refers to *an ecosystem large enough to allow observation and understanding of the interaction of disturbance, geomorphic, and topographic dynamics with the biota*. In other words, a large collection of forest stands, whose common link is their dynamic relationship of disturbance to the land features (Forman and Godron 1986). In the foothills of Alberta, a landscape may be anywhere from 100,000 to 1,000,000 hectares. Like any ecological definition, this one is arguable, but it does allow some convenient scale distinctions to be made:

1) Regional

Several landscapes spatially related and commonly influenced by regional climatic patterns. The Model Forest study area is a region, in which several large landscapes have been identified with unique topographic, biotic, and pattern (disturbance) features. Beyond a region is a biome.

2) Landscape

Ecosystems that share common disturbance and land associations, as well as the resulting arboreal (tree) relationships with disturbance and land features. The ecological natural subregions have proven useful in defining landscapes (which include the Lower Foothills, Upper Foothills, Subalpine east, Subalpine west, and the Montane – see Figure 2).

3) Meso / Disturbance

Areas within a landscape that at some point in time and space are commonly affected by one disturbance event. Usually involves multiple stands.

4) Stand

An ecosystem with homogeneous forest structure and composition, as well as land features (*i.e*. an ecotope). Stands are recognisable as units visually.

5) Patch

Contiguous area of land that share common physical or biological characteristics. Age patches share year or year-range of origin (such as Old Forest), type patches depict areas of common tree species combinations, and Alberta Vegetation Inventory Patches define complex combinations of age, tree species, density and height, other vegetation, and other site factors. Relevant to this report, there are also *disturbance patches*, which have been affected similarly by a disturbance event, and *remnant patches*, which are any areas that have not been disturbed within a disturbance event.

6) Island

One type of remnant patch within a disturbance patch. There are no size limits on islands at this point, but they tend to be small. Islands may also be any combination of age, type and non-operable land.

7) Matrix

All undisturbed land outside the boundaries of disturbance events. Thus, any part of a landscape that is not within an event is matrix. *Matrix remnants* are undisturbed residual land within an event, but physically attached to the surrounding matrix.

The geographical terminology used in this document is as follows. The Foothills Model Forest consists of two major land areas divided by the Rocky Mountains (see Figure 1). To the west of the foothills lies approximately 1.1 million hectares of Jasper National Park. To the east of the mountains is an area of approximately the same size, which covers the Hinton Wood Products Forest Management Area (FMA) but also includes Switzer Provincial Park, the town site of Hinton, a large coal mine, and a strip land under the management of Alberta Sustainable Resource Development Public Lands and Forests. Outside the boundary of the FtMF, but still in our study area is approximately 370,000 hectares that is the ANC FMA (Figure 1). The area to the west of the foothills is all Jasper National Park, and will be referred to as such. Since the area to the east of the mountains is a mixture of tenure, it will simply be referred to as the "foothills east".

Within Jasper National Park, three natural subregions exist: the Montane, Subalpine, and the Alpine. In the foothills east there are three main natural subregions: Lower Foothills, Upper Foothills, and Subalpine (Figure 2). To avoid confusing the two subalpine areas, they will be referred to as the "Subalpine west" and "Subalpine east".

THE DISTURBANCE ECOLOGY METHODOLOGY SERIES

This methods report is the second in a series that will be published by the Foothills Model Forest on methods we use to study natural disturbance dynamics on foothills and mountain landscapes in Alberta. We also publish a research series which details the results of our research- the reports currently available in this series are listed below.

For more information on the FtMF Natural Disturbance Program, or the Foothills Model Forest, please contact the Foothills Model Forest in Hinton, Alberta at (780) 865-8330, or visit our website at: **http://www.fmf.ab.ca**

Reports available in the research series:

Andison, D.W. 1999. Assessing forest age data in foothills and mountain landscapes in Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 1. December, 1999. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 2000. Landscape-level fire activity on foothills and mountain landscapes in Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 2, July, 2000. Foothills Model Forest, Hinton, Alberta.

Andison, D.W., and K. McCleary 2002. Disturbance in riparian zones in foothills and mountain landscapes of Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 3, February, 2002. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 2003. Patch and event sizes on foothills and mountain landscapes of Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 4, March, 2003. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 2003. Disturbance events on foothills and mountain landscapes of Alberta. Part 1. Alberta Foothills Disturbance Ecology Research Series, Report No. 5, November, 2003. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 2004. Island remnants on foothills and mountain landscapes of Alberta Part II on Residuals. Alberta Foothills Disturbance Ecology Research Series, Report No. 6, November, 2004. Foothills Model Forest, Hinton, Alberta.

Reports available in the methodology series:

K. MacLean, K. McCleary, D. Farr and D.W. Andison. 2003. Island remnants on foothills and mountain landscapes of Alberta: Methods. Alberta Foothills Disturbance Ecology Methodology Series, Report No. 1, November, 2003. Foothills Model Forest, Hinton, Alberta.

Part 2: METHODS

INTRODUCTION

Field sampling as a means of ecological data collection can be costly and time-consuming. And given this, we cannot confidently say that field data collection most accurately reflects what is actually on the ground. Aerial photo interpretation has been used to inventory structural features, with large-scale low-level photography being used to inventory forest regeneration for silvicultural surveys. In this study, we set out to determine whether interpretation of large-scale aerial photos would provide a viable alternative to field sampling as a means of inventorying forest structure. For interpretation to be a superior alternative, it would have to be both cost effective and produce counts that were close to those generated from field data. Although we have no information on the accuracy of field collected counts, we assume here that field data is more accurate than interpretation due to the fact that people can see and touch the features versus interpret them from remotely an image.

The objective of this project was to assess the use of low-level aerial photography (compared with field data collection) to inventory structural features. We rated the 2 inventory methods by 1. cost, 2. amount of time it took to collect the data, and 3. level of precision. In this report, we provide a critical review of using aerial photography interpretation as a viable method to inventory structural features.

STUDY AREA

The study area was the Dogrib Fire, located west of Sundre, Alberta in the Red Deer River watershed. The fire was contained in the Sundre Forest Products Forest Management Agreement (FMA) area, the Eagle Creek Forest Recreation Area and Panther Corners Forest Land Use Zone (FLUZ) (Figure 1). The fire occurred in October 2001 and encompassed 9,214 hectares. The natural subregions of the area include the Upper Foothills and Subalpine (Archibald et al. 1996). A detailed description of the study area including climate, vegetation, geology and surficial material can be found in McCleary (2005).

METHODS

REACH SELECTION

Staff from the Foothills Model Forest Fish and Watershed Program selected stream reaches within the fire in the Sundre Forest Products FMA. Reaches were grouped by drainage area and stream reach slope classes. We identified potential reaches that represented the range of the above classes.

AERIAL PHOTOGRAPHY

In November 2002, we contracted Timberline Forest Inventory Consultants to survey 27 candidate stream reaches by helicopter. Based on their suggestion, we selected a flying height of approximately 180m to achieve maximum photo coverage. Eight of the selected reaches were eliminated during the flight due to the presence of anthropogenic disturbances (i.e. roads, harvest blocks, salvaging) within 50 meters of the stream. Aerial photographs were taken for 19 reaches at an average scale of 1:1,800 (Appendix 1). Actual photo scale varied between 1:1596 and 1:2065. Table 1 shows the breakdown of reaches by slope and drainage class. Reaches 13 and 18 were eliminated later due to the presence of anthropogenic disturbances that were estimated as greater than 50 meters from the stream at the time of photography.

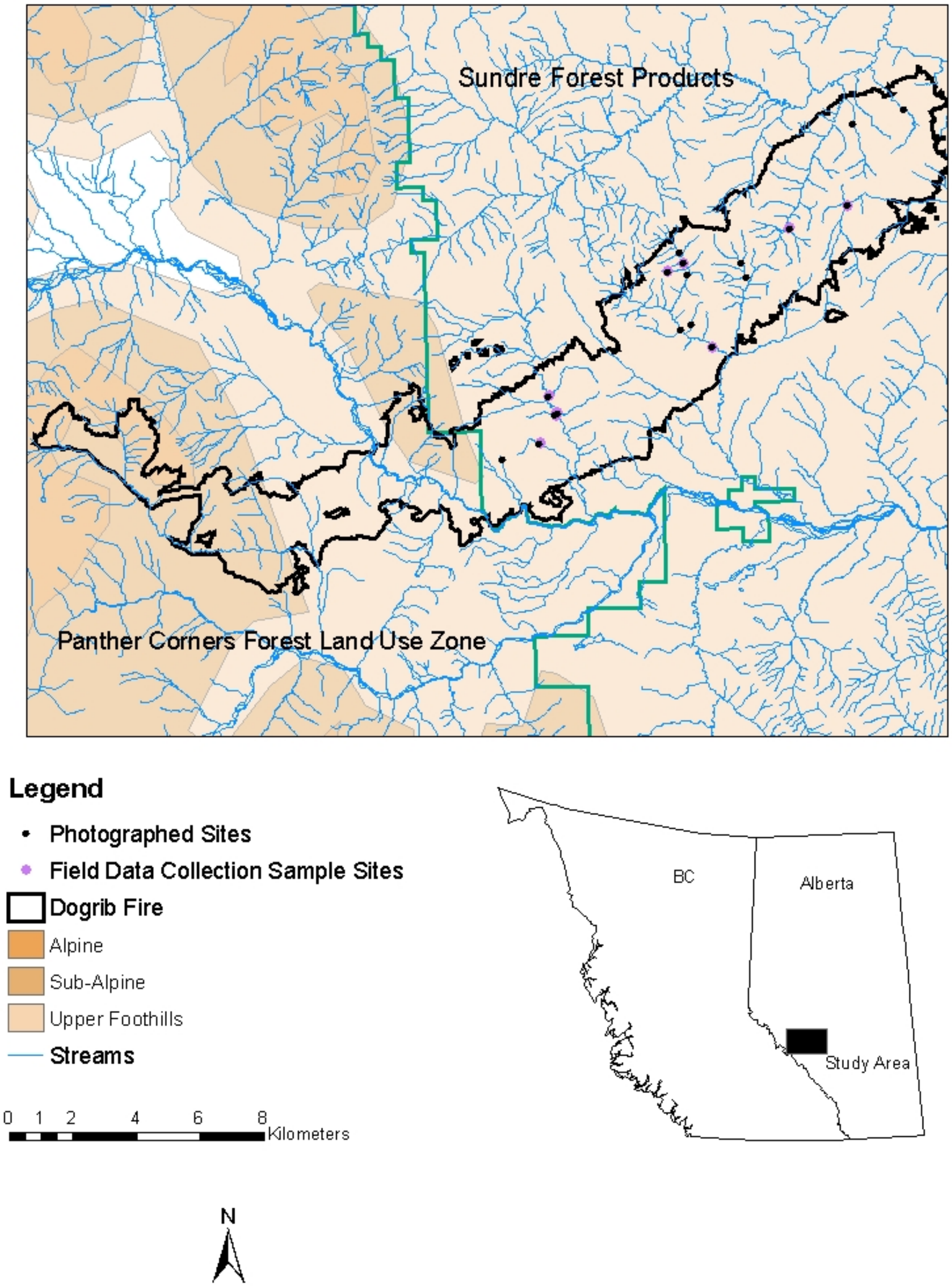


Figure 1. Partial map of Alberta showing natural sub-regions, fire boundary and sample site locations for the Managing Disturbances in Riparian Zones study.

Table 1. Slope and drainage class of photographed stream reaches, Managing Disturbance in Riparian Areas study.

	Drainage area		
	< 1 km^2	1-5 km^2	> 5 km^2
Percent slope			
0-4%	1, 11, 21	2, 12, 22	3, 15, 26
4-10%	1, 4, 7, 11, 24	5, 25	6
10-20%	7, 13, 17, 18	0	0
> 20%	8	0	0

PHOTO INTERPRETATION

Timberline used the computer-interfaced Ross SFS-3 Stereocomparator to inventory structural features on the photos. The device provides a 10 times magnification and at 1:1,800 scale has an effective resolution for ground distances of 0.1m.

Plot boundaries (10m by 10m) were located and referenced from aerial photographs supplied by field crews of the Foothills Model Forest.

Trees

The following data was collected on all standing trees greater than 1.3 m tall: species, dbh class (7.5 to 15 cm, 15 to 30 cm, and 30+ cm), height class (<=1m stumps, >1-5m, >5-10 m and >10m), live/dead status, whether the tree was dead at the time of the fire, and condition of the bole. A mark was placed on each tree on the laser copy once it had been measured to avoid measuring the same tree more than once.

Coarse Woody Debris

The following data was collected on all pieces greater than 1m in length: species, length, diameter at both ends, decay class, whether the piece was coarse woody debris or a snag at the time of the fire, where the piece originated and it's current location. Only pieces within the plot boundary were measured. Diameters were measured at each end of the piece and recorded to the nearest 10 cm. A mark was placed on each tree on the laser copy once it had been measured to avoid measuring the same tree more than once.

Table 2 details possible hinderances to interpretation encountered by the interpreter.

Table 2. Assessment of quality of aerial photos, Managing Disturbance in Riparian Areas Study.

Photo/Plot	Photo Location	Snow	Shadows	Other Potential Issues
11	no issue	yes	no	none
8	no issue	yes	yes	none
6	no issue	no	no	none
12	no issue	yes	no	Upland area is very dark
7	no issue	no	yes	none
3	no issue	yes	no	none
5	no issue	yes	yes	none
15	no issue	no	yes	none
1	no issue	no	yes	none

FIELD DATA COLLECTION

We sampled 10 by 10 m square plots in both the riparian and upland areas of 8 of the 19 stream reaches (Figure 2). Riparian plots straddled the stream to sample the riparian area. Upland plots were located in the upland, 20 meters away from the riparian plots.

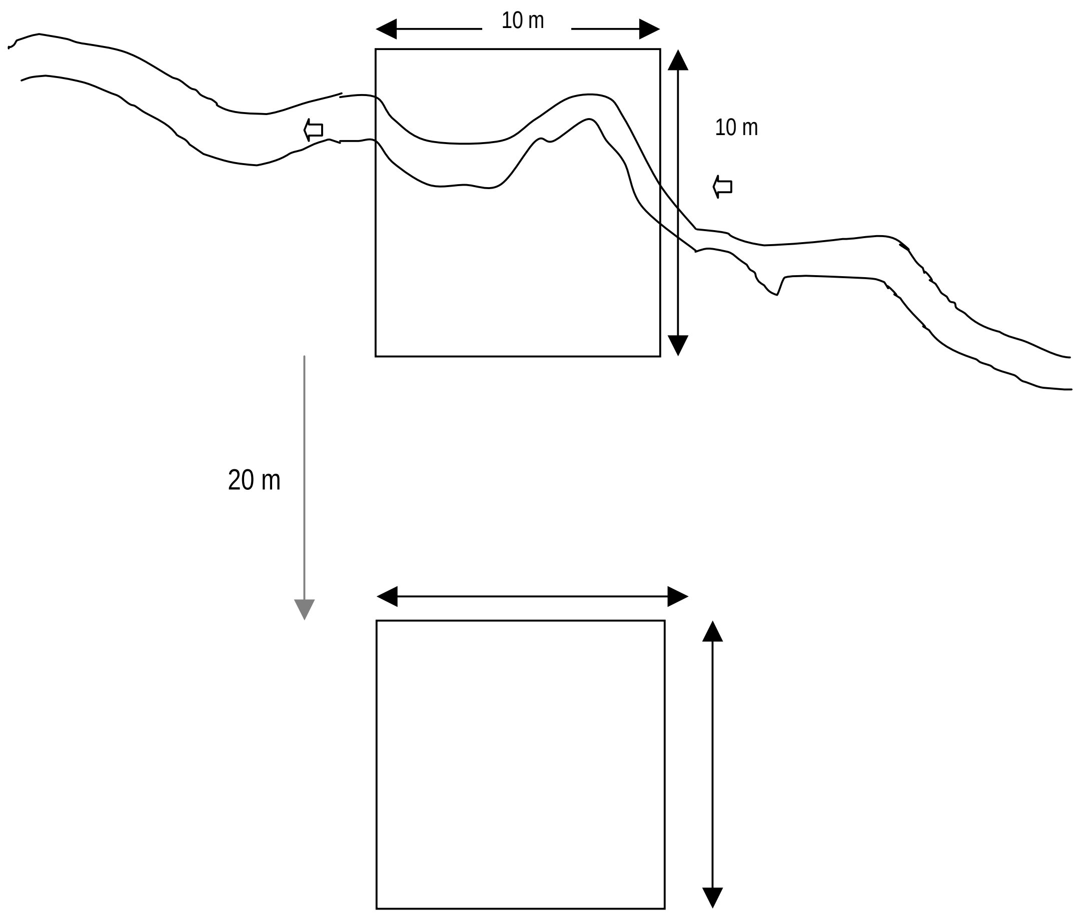
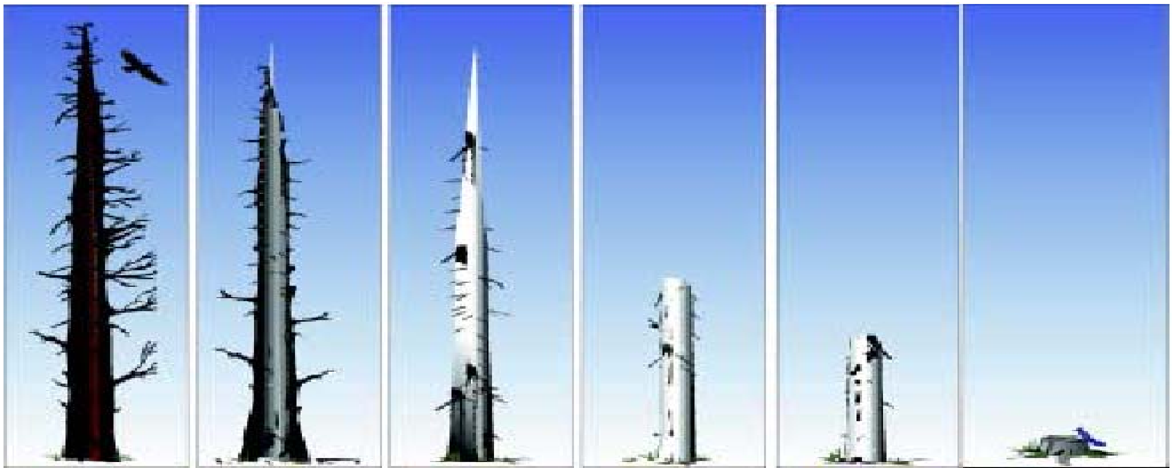


Figure 2. Plot dimensions and relative locations for riparian and upland plots, Managing Disturbance in Riparian Areas study.

We collected the following information on all trees within the plot greater than 7.5 cm dbh: species, dbh class (7.5 to 15 cm, 15 to 30 cm, and 30+ cm), height class (<=1m stumps, >1-5m, >5-10 m and >10m), live/dead status, whether the tree was dead at the time of the fire, which piece of coarse woody debris it was associated with (if any) and condition of the bole (damage class, Figure 2). For the purposes of this study, we defined coarse woody debris as any fallen or suspended (not self-supporting) dead tree bole recognizable as a log. We collected the following information on all pieces of debris completely or partially within the plot that were at least 1 meter long AND at least 10 cm diameter at one end of the pieces: species, tree number it was associated with (if any), length, diameter at both ends, decay class, whether the piece was coarse woody debris or a snag at the time of the fire, where the piece originated and it's current location. A detailed description of field methods can be found in the report "Stand Dynamics Field Procedures Manual Dogrib Fire, 2003" by MacLean and McCleary.



1	2	3	4	5	6
Bark intact	Bark missing	Clean snag	Broken above breast height	Broken below breast height	Cut stump
Trees that are recently dead with bark intact. Branches and needles may also be intact	Trees that have been dead several years on which the bark is partially deteriorated and fallen off; tops are often broken	Trees that have been dead several years with no bark left. Usually most of the branches will be gone as well; tops are often broken	Trees that have been dead a long time with no bark, extensive decay, and that are broken above BH	Postburn trees that extended above BH preburn, but no longer do.	Postburn trees that stood preburn and was cut as a result of fire operations

Figure 2. Tree damage classes used in Managing Disturbance in Riparian Areas study (adapted from USDI National Park Service. 2003).

RESULTS

Do low-level aerial photos provide enough detail to reliably inventory structural features?

Precision

We summarized number of pieces of coarse woody debris and number of trees counted by field crews and by the photo interpreter for each plot and compared the two values. We calculated the percent difference between the interpreted values and the data collected in the field using the following equation ((interpreted value-field value)/field value)*100).

In almost all cases, the photo interpreter counted fewer trees and pieces of coarse woody debris than the field crews on the same plot. The difference in number of features counted was usually at least half (i.e. if the field crews counted 10 trees, the interpreter counted 5). Figures 3 and 4 show the difference in counts for number of trees and CWD. This relationship was consistent despite the size of the piece or tree (we thought that perhaps the interpreter might be less able to see small pieces or trees) (Figure 5) and did not appear to be related to the quality of the photo. We assume that the number of features counted by the field crews was more accurate than that counted by the interpreter. Analysis done on instream woody debris by McCleary found large differences in number of pieces and piece diameter between field counts and interpreted counts while he found small differences in piece length calculated from the two methods (McCleary 2005). It appears that interpretation of photos at the scale of 1:1800 can provide adequate estimates of volume (because large wood that is visible to the interpreter represents most of the volume) but not counts or size.

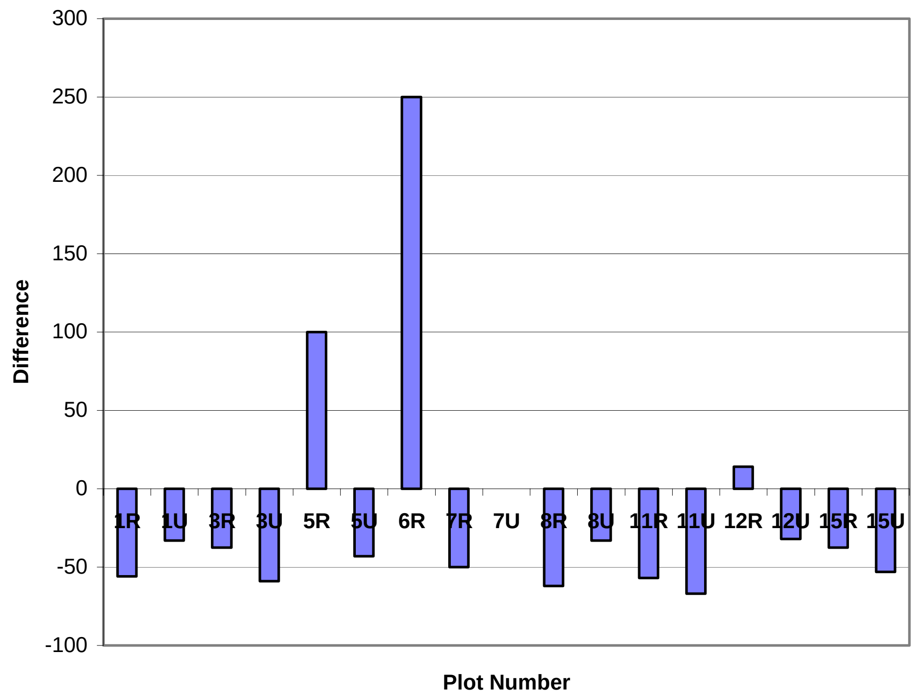


Figure 3. Difference in counts of number of trees between field and photo interpretation, Managing Disturbance in Riparian Areas Study.

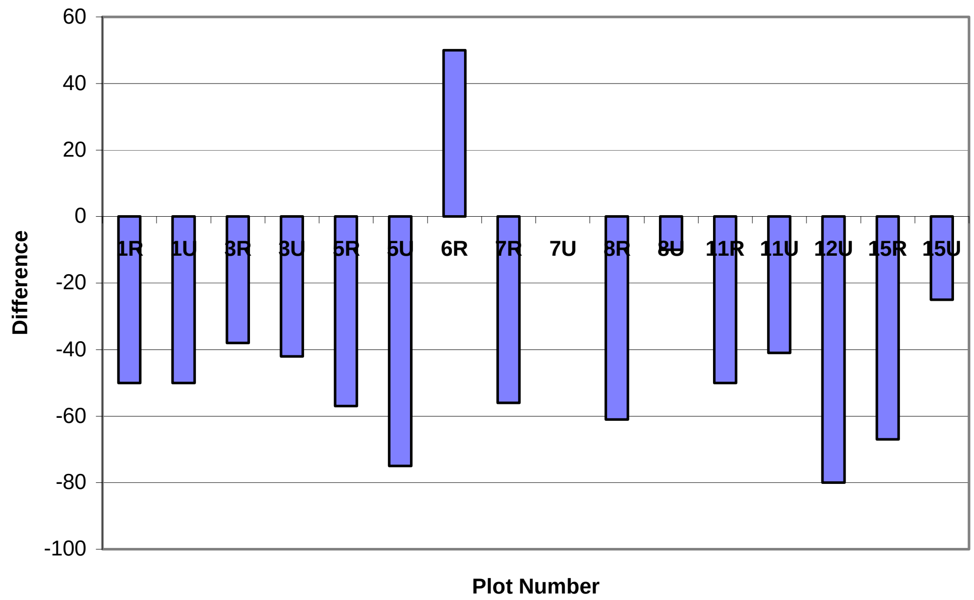


Figure 4. Difference in counts of number of pieces of CWD between field and photo interpretation, Managing Disturbance in Riparian Areas Study.

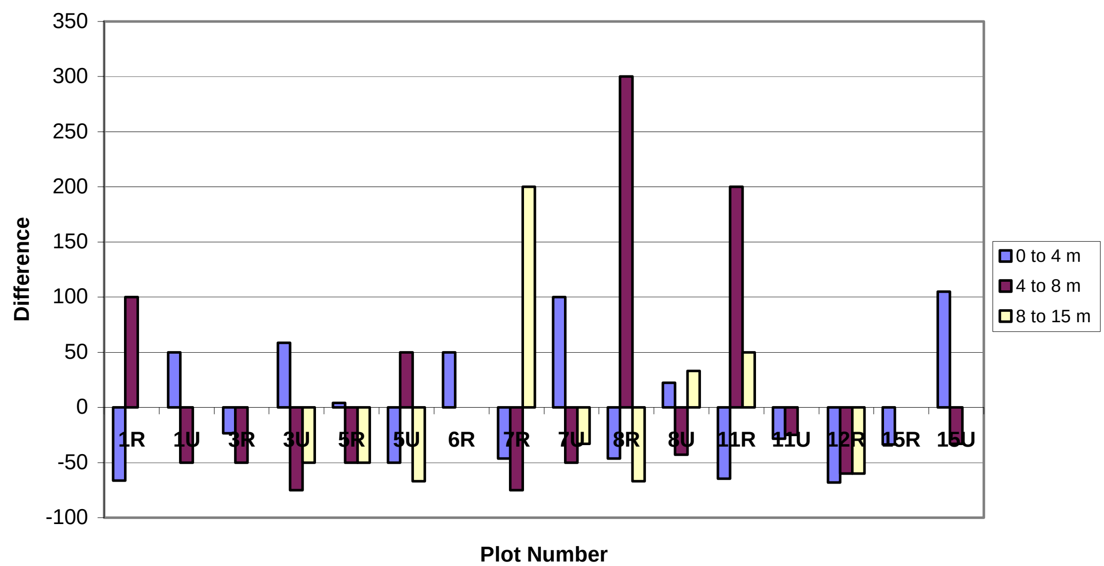


Figure 5. Difference in counts of number of pieces of CWD by 4 m length classes between field and photo interpretation, Managing Disturbance in Riparian Areas Study.

Cost

Costs of field data collection were lower than photo interpretation, with photo interpretation costing approximately $23,000 and field data collection costing just over $14,000 (Table 3)

Table 3. Detailed costs for field data collection and photo interpretation, Managing Disturbances in Riparian Areas Study.

Collection Method	Item	Amount	Total
Field data collection	Personnel costs	12804.39	
	Travel costs	1368.53	14172.92
Photo interpretation	Consultant (Timberline)	12471.12	
	Helicopter	7114.56	
	Administration (FMF)	3274.20	22859.88

Time

Field data collection required 0.5 weeks for study design, 5 weeks for project management and 18 person weeks for preparation for field work (site selection, map development, logistics planning) and actual field data collection (Table 4). Photo interpretation took half the time, requiring a total of 7.75 weeks to complete the project, with field data collection taking 14.5 total weeks to complete the project.

Table 4. Detailed time breakdown for field data collection and photo interpretation, Managing Disturbances in Riparian Areas Study.

Collection Method	Item	Weeks	Total
Field data collection	Study design	0.5	
	Project management	5	
	Field work (2 people)	9	14.5
Photo interpretation	Field data collection	1	
	Film Processing	2.11	
	Photo interpretation	4.11	
	Administration	0.5	7.75

Discussion

Precision

We found large differences in data collected in the field versus data interpreted from aerial photos. Some possible explanations include true differences in number of features on the site at the time of sampling and at the time of photography, poor photo quality and using an inappropriate photo scale for the level of detail required in this study.

After field crews established the plot in the field, they marked the location of the plot on the photo using reference points that could be identified on both the ground and in the photo. If field crews were not able to accurately mark plot locations on the photos, the field crews and photo interpreter would have been sampling different plot areas, which would explain the differences in number of features counted. Another possible explanation is that pieces of CWD were moved (by cows, horses or water) since the photo was taken. Pieces could have incinerated during the fire but looked like in tact pieces on the photo. Lastly, pieces could have decayed between the time the photos were taken (November 2002) and the year plots were sampled in the field (October 2003), thus being identified as CWD by the interpreter but not the field crews. These last three explanations are unlikely, since in all cases MORE pieces of CWD were identified in the field than on photos on all but 2 plots.

In terms of photo quality, one possible source of error is the presence of shadows on the photos being mistaken as trees or coarse woody debris. The photos were flown in late November. Shadows could be mistakenly identified as trees or CWD or tree or CWD length could have appeared longer than they actually were. Indeed, the photo interpreter noted that shadows made interpretation difficult on 5 of the 9 photos. Another factor that may have influenced the accuracy of the both the field and interpreted measurements is the amount of snow that was on the ground at the time of sampling and the time of photography. Field data was collected in October and November and although presence of snow was not noted at the time of data collection, it is very possible in the study area at this time of year. Snow is evident on more than half of the photos.

The photo interpreter also thought that although diameter estimates are thought to be accurate to 10 cm, diameter classes may better reflect size estimates by not giving the impression of false accuracy that comes with a number.

Cost and Time

The photo interpretation exercise cost quite bit more than field data collection. Collecting data in the field cost 40 % less than did the photo interpretation exercise. As expected, it was much quicker to collect data via photos than in the field, with photo interpretation taking roughly half the time it took to collect data in the field. It is our opinion that it is not worth sacrificing precision for speed.

Conclusions

Measurements of structural features taken from aerial photos flown at 180 m do not provide an acceptable level of precision for use in our research. If we want to replace field sampling with aerial photography, one option is to use photos taken at a higher resolution. The photo interpreter for this project, Derrick Lalonde, suggests a flying height of 50m (versus the 180m flying height used in this project). This is the height used in silviculture surveys. At this height, photo coverage is approximately 20m by 26m. Given that the costs and levels of precision between field work and photo interpretation, field data collection appears to be the best way to collect structural data for our purposes.

5.0 LITERATURE CITED

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USDI National Park Service. 2003. Fire monitoring handbook. Boise (ID): Fire Management Program Center, National Interagency Fire Center. 274p.

Using Low-Level Aerial Photography to Measure Structural Features

Alberta Foothills Disturbance Ecology Methodology Series
Appendix 1

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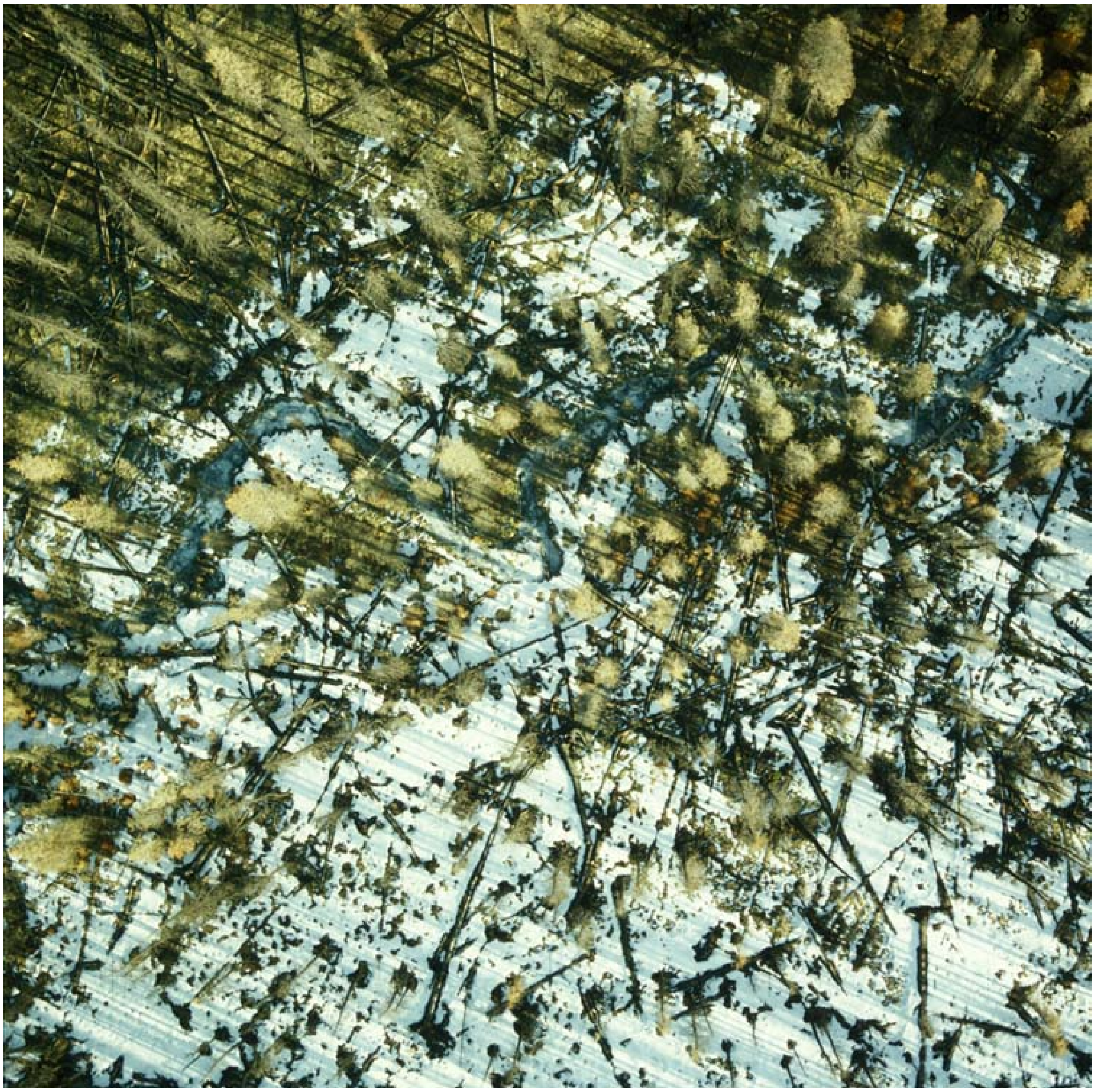
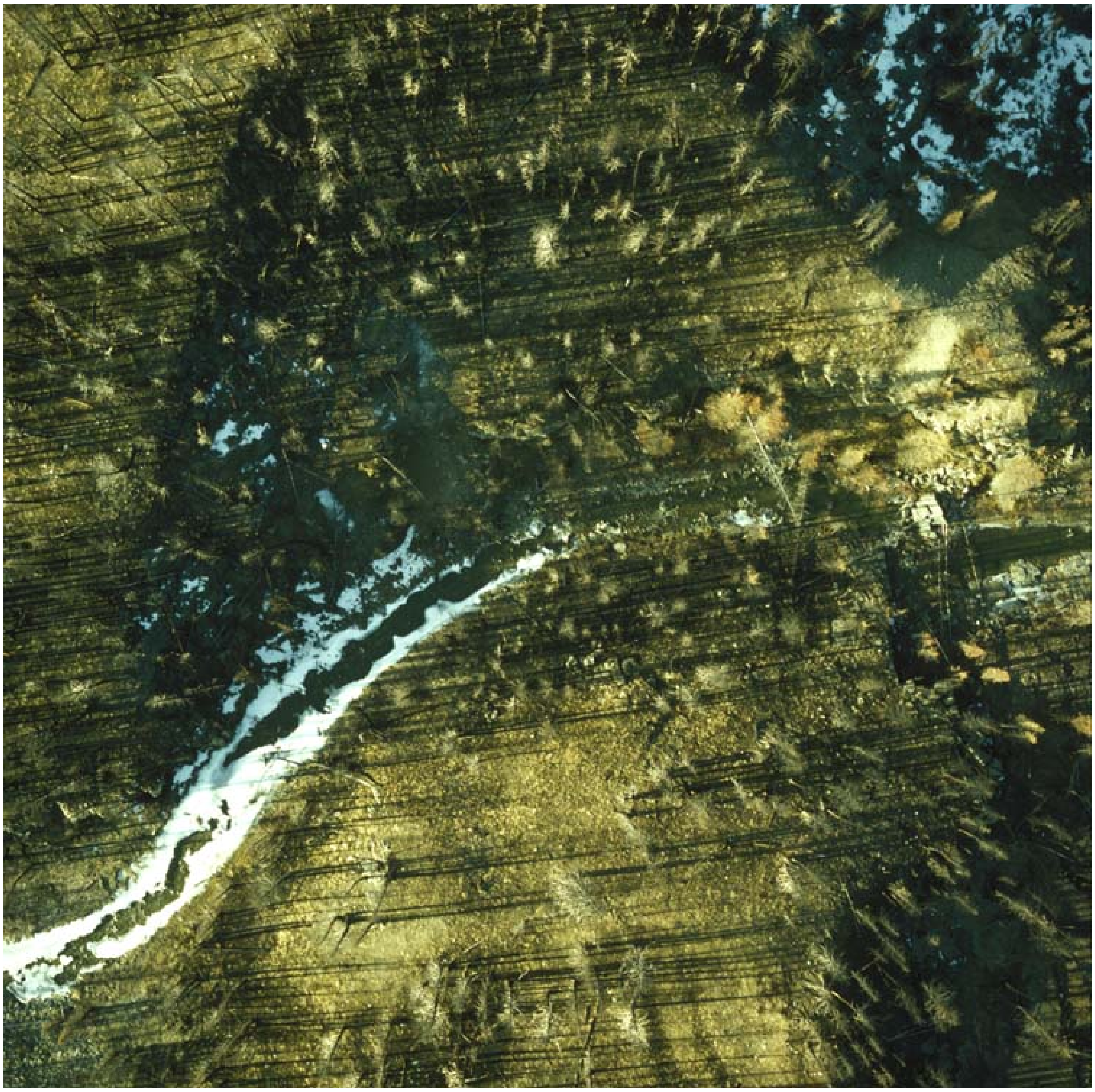
Foothills Model Forest
October 2005

Appendix 1 Figure 1. Air photo, Reach 3-27.

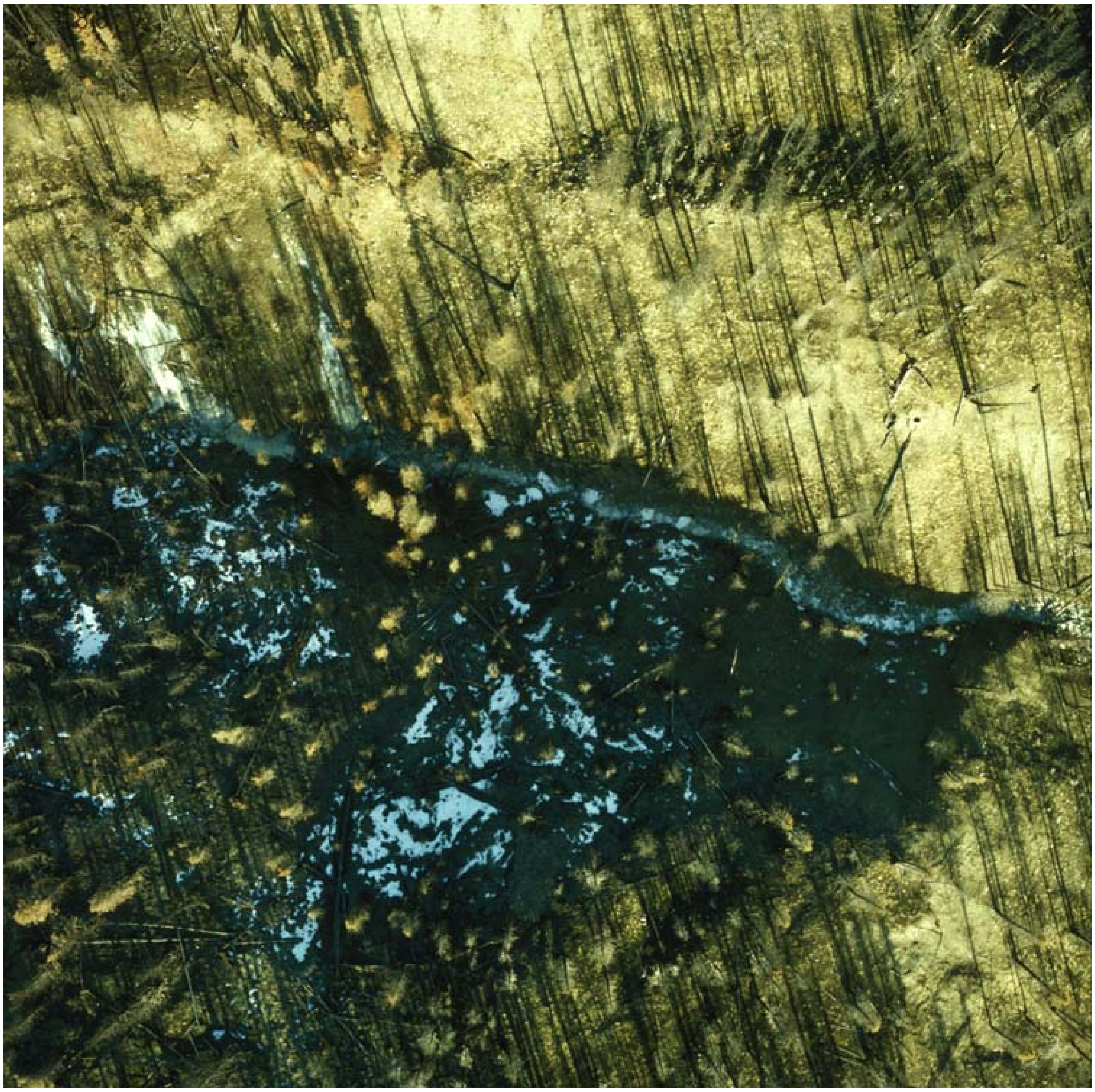
Appendix 1 Figure 2. Air photo, Reach 5-11.



Appendix I Figure 3. Air photo, Reach 6-33.

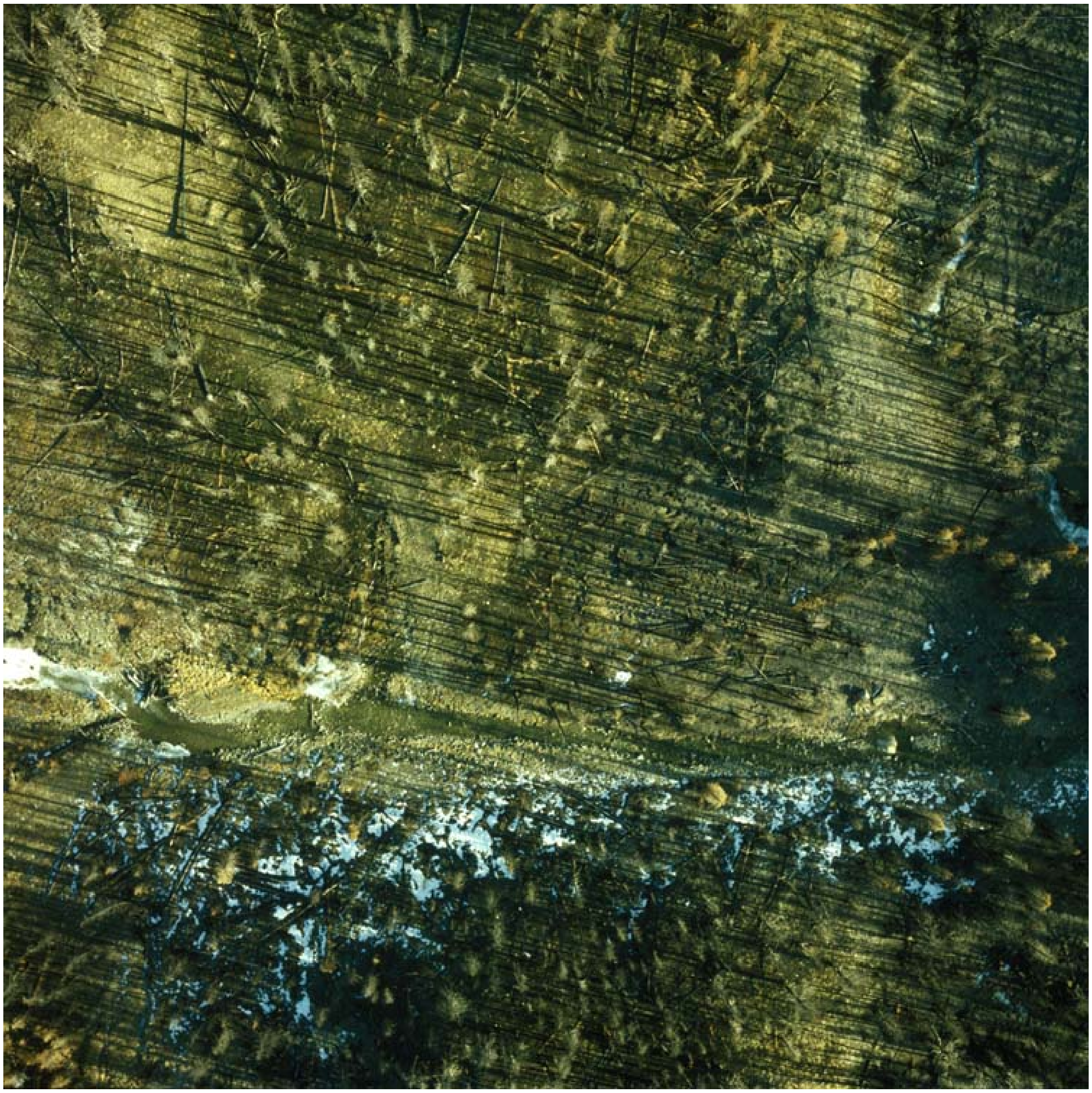


Appendix I Figure 4. Air photo, Reach 7-6.

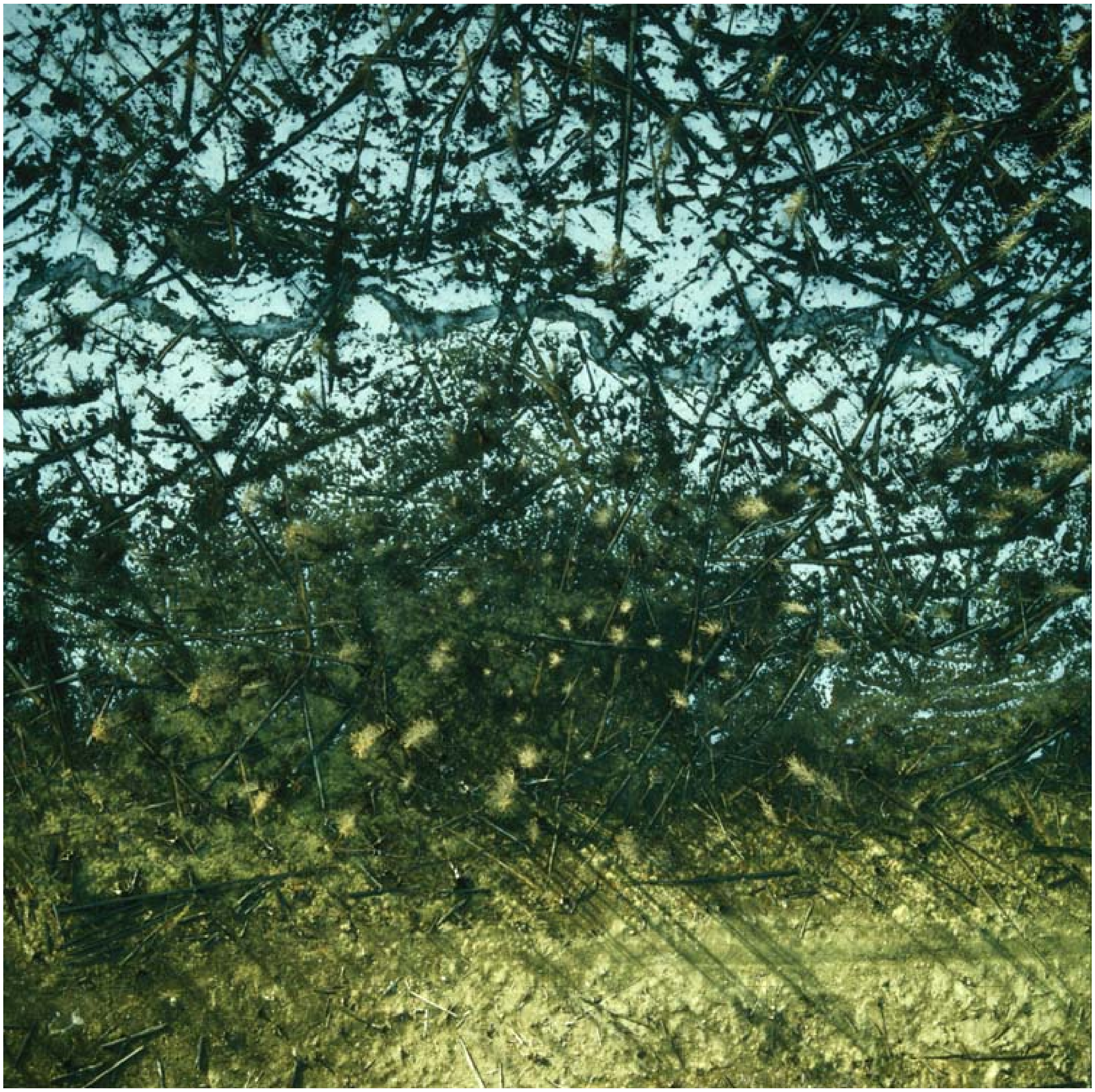


Appendix 1 Figure 5. Air photo, Reach 12-2.

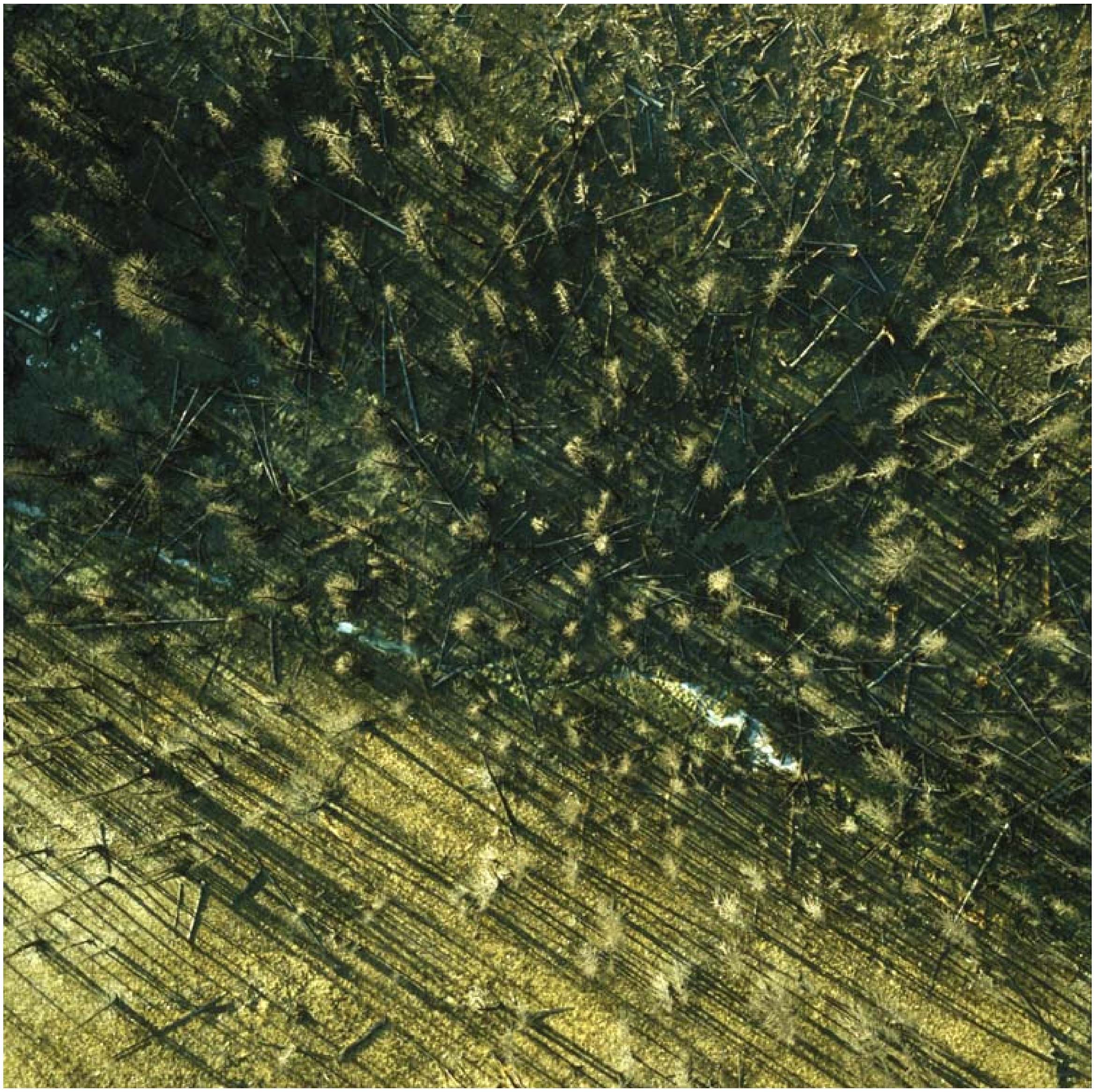
Appendix I Figure 6. Air photo, Reach 15-5.



Appendix 1 Figure 7. Air photo, Reach 11-2.

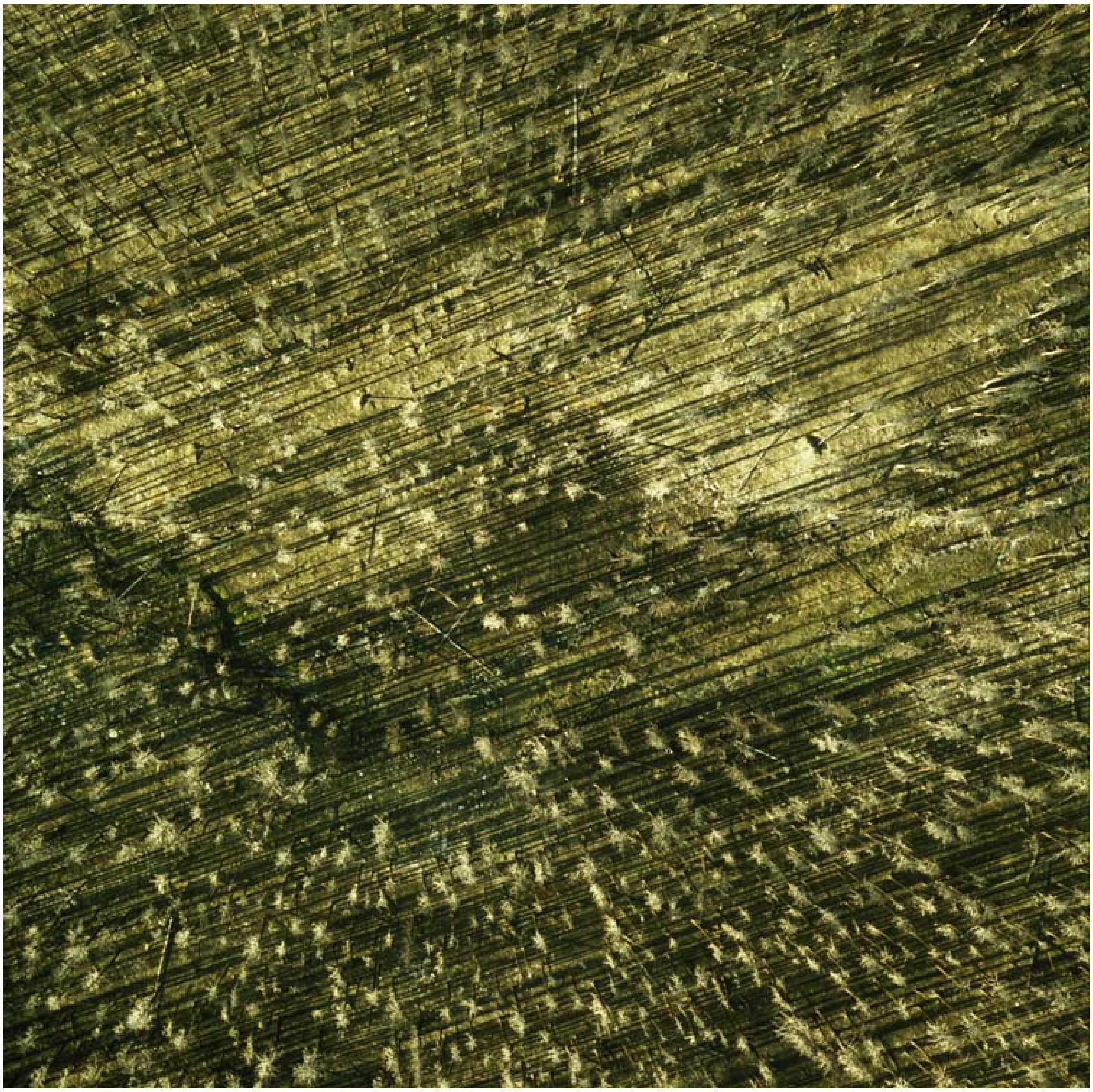


Appendix 1 Figure 8. Air photo, Reach1-14.

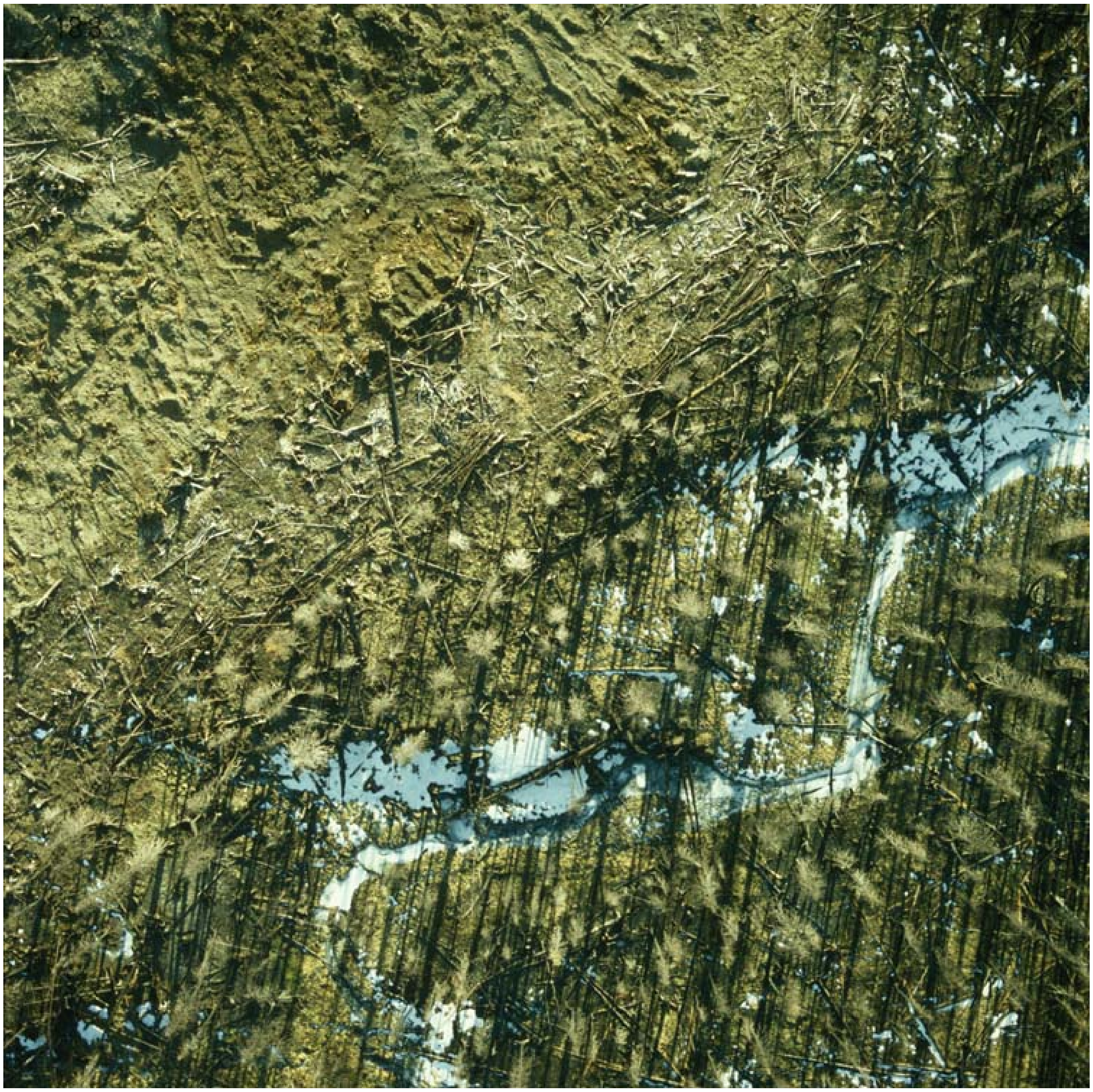


Appendix I Figure 9. Air photo, Reach 13-9.

Appendix 1 Figure 10. Air photo, Reach 17-10.



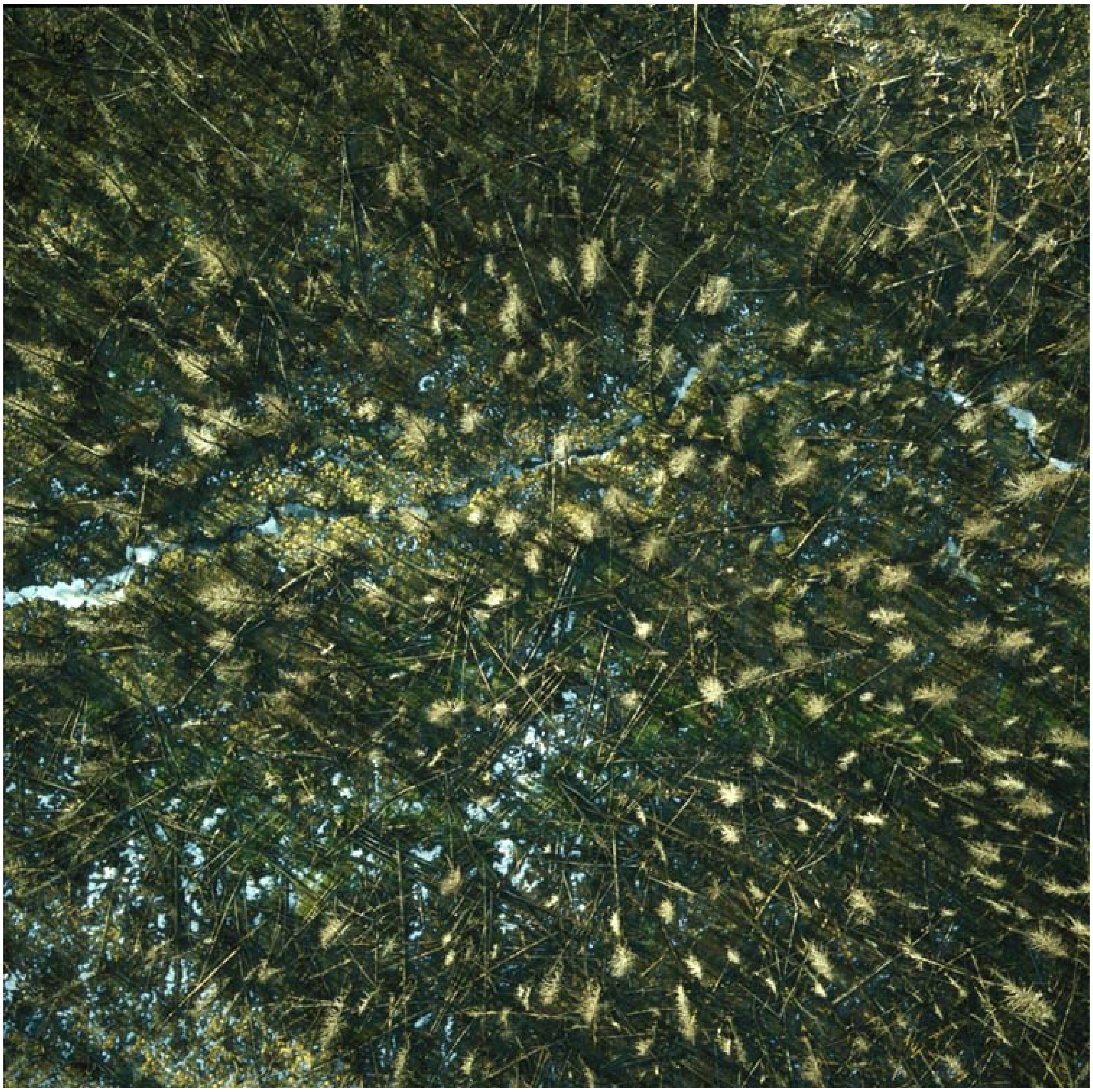
Appendix 1 Figure 11. Air photo, Reach 18-1.



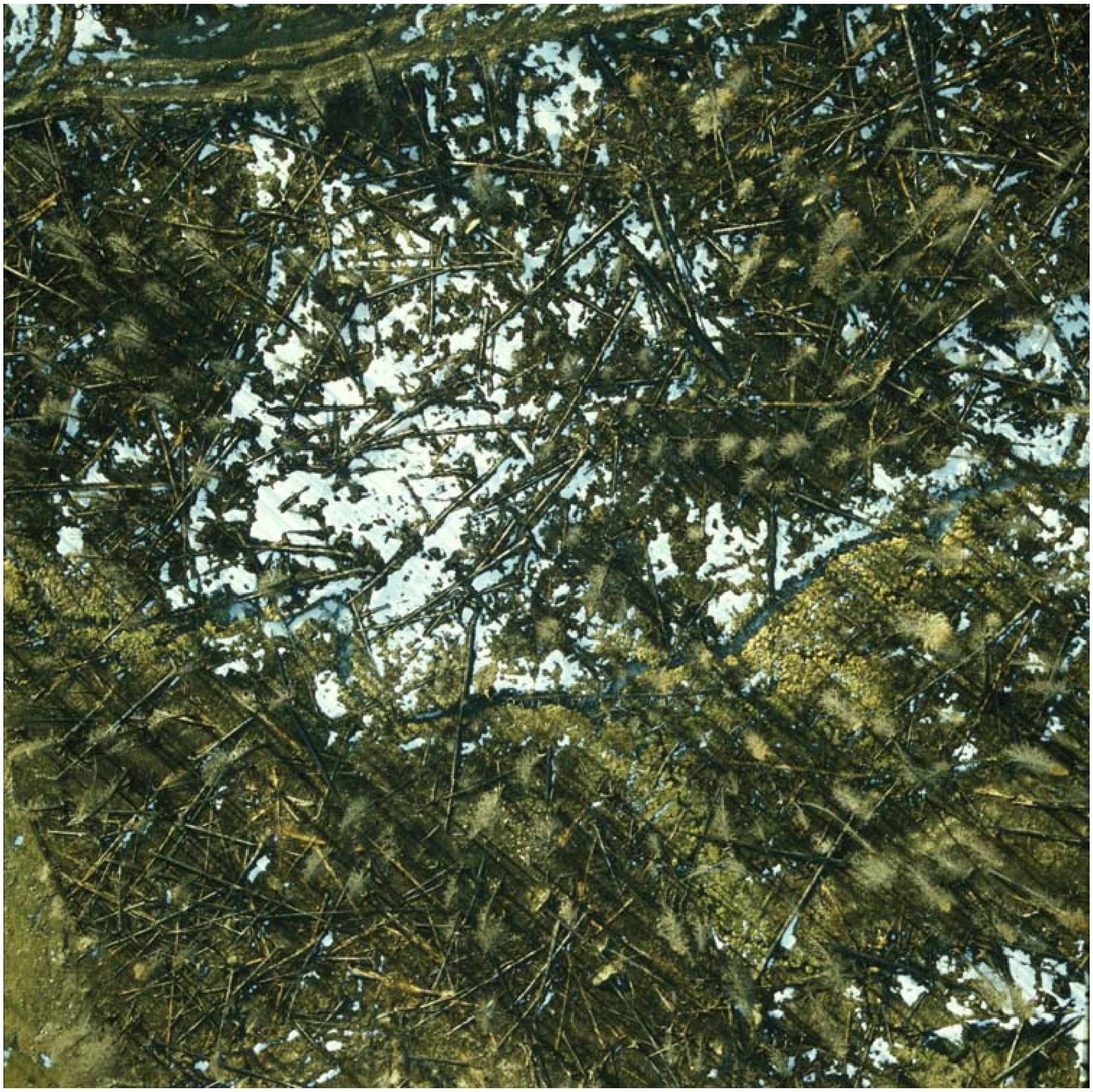
Appendix 1 Figure 12. Air photo, Reach 2-02.

Appendix 1 Figure 13. Air photo, Reach 21-8.

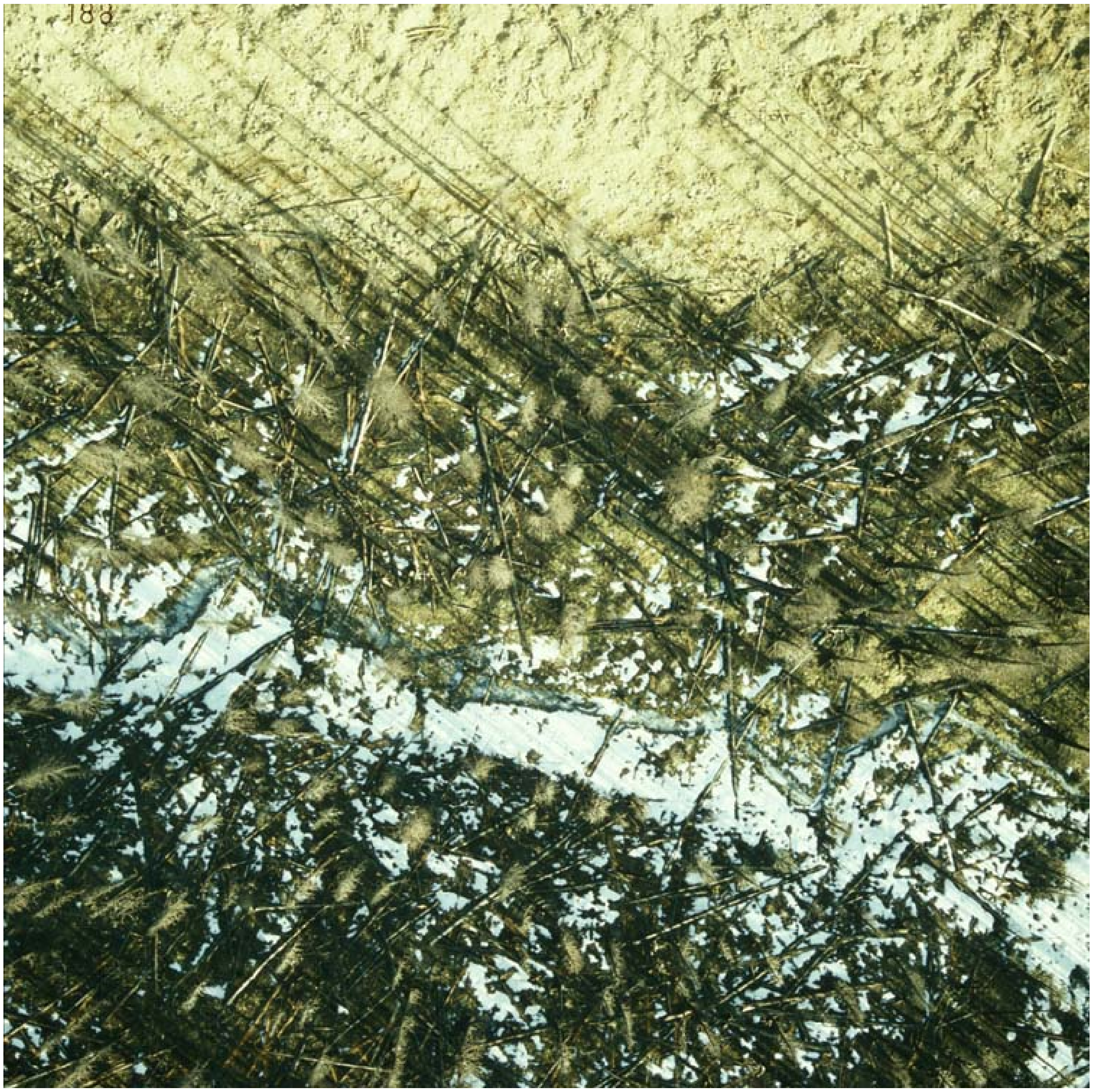
Appendix I Figure 14. Air photo, Reach 22-09.



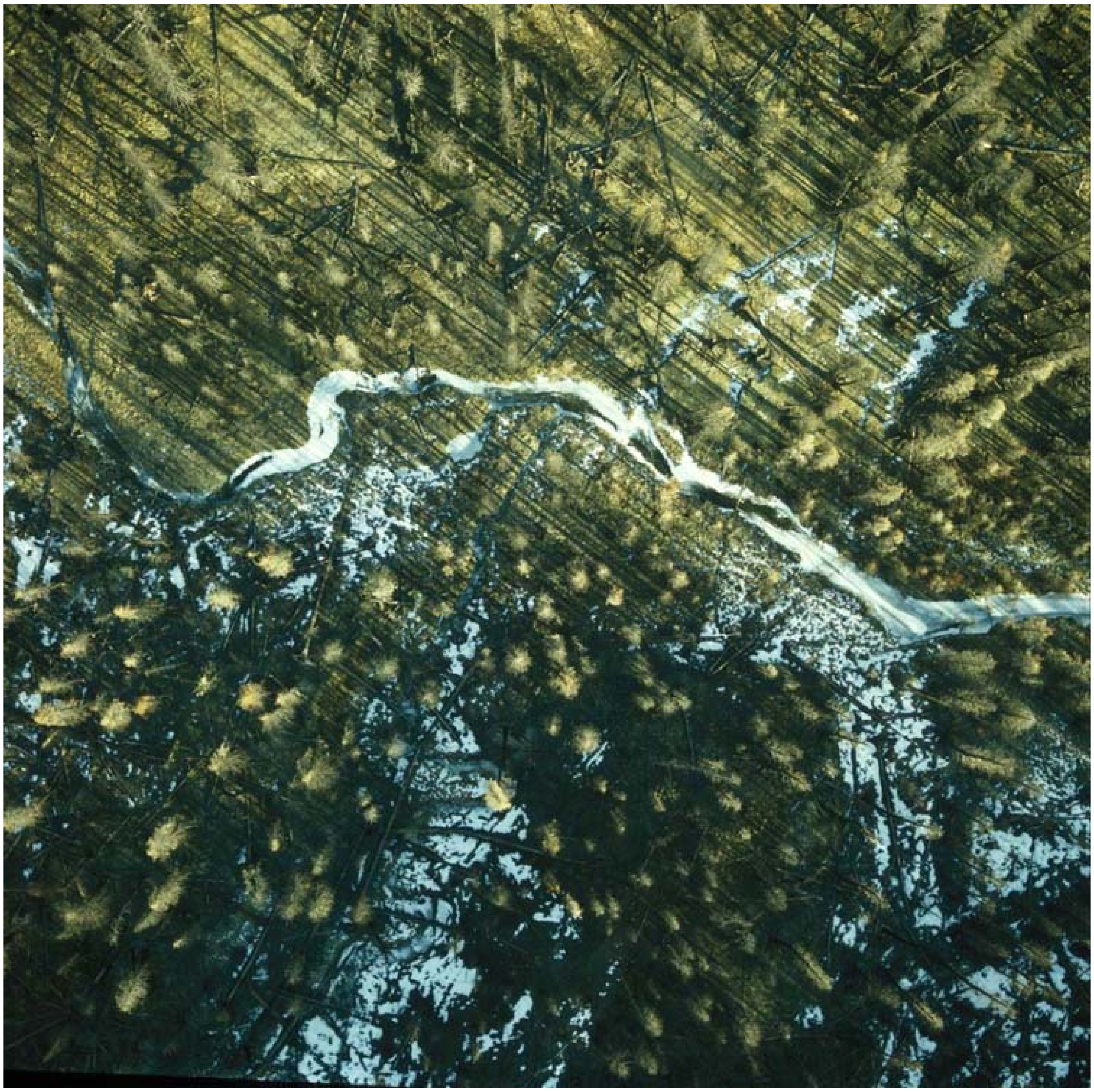
Appendix 1 Figure 15. Air photo, Reach 24-23.



Appendix 1 Figure 16. Air photo, Reach 25-5.



Appendix 1 Figure 17. Air photo, Reach 4-3.



Appendix 1 Figure 18. Air photo, Reach 8-15.